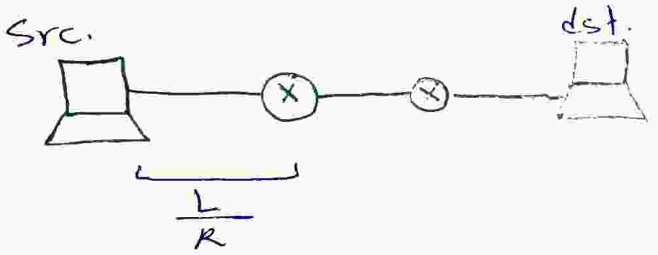
Sheet 1

2) equation 1.1 gives formula for end-to-end delay of sending one Packet of length L over N links of transmission rate R. Generalize this formula for sending P such Packets Pack-to-Pack over N-links.

$$d_{end-to-end} = N\frac{L}{R}$$



Generalize for (P) Packets

$$d = (N+P-1)\frac{L}{R}$$

Zero index

0	$\frac{L}{R}$	$\frac{2L}{R}$	$\frac{3L}{R}$	$\frac{4L}{R}$	$\frac{5L}{R}$
$P_1 \to$ src	$P_1 \to R_1$	$P_1 \to R_2$	$P_1 \to$ Dst	$P_2 \to$ Dst	$P_3 \to$ Dst
	$P_2 \to$ SRC	$P_2 \to R_1$	$P_2 \to R_2$	$P_3 \to R_2$	
		$P_3 \to$ src	$P_3 \to R_1$		

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[3] Consider app transmits data at steady ~~state~~ rate (for ex. sender generates N-bit unit of data every K-time units), K → small & fixed) Also when such an app starts, it will continue running for a relatively long period of time, Answer the following bereifly.

a) would that packet-switched or circuit switched is appropriate for this app? why?

↳ circuit switched, it requires long time and sends at fixed rate.

b) suppose that ~~this is~~ packet-switched used and ~~for~~ only traffic in this network comes from such apps. as described above & assume that sum of app. data rates less than capacities of each and every link. Is some form of congestion control needed? why?

↳ no need for congestion control, since the data rate is less than the capacity

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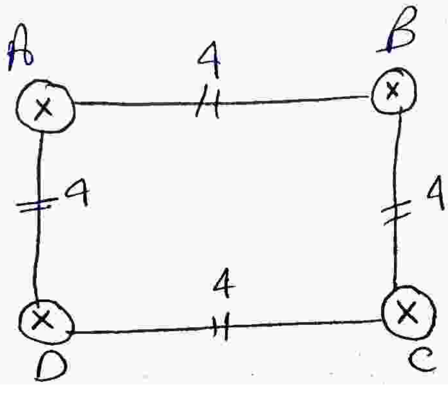
④ Consider circuit-switched in figure 1-13 Recall that there are 4 circuits on each link, label the four switches A, B, C, D going in clockwise direction

a) what is maximum number of simultaneous connections that can be in progress at any one time in this network?

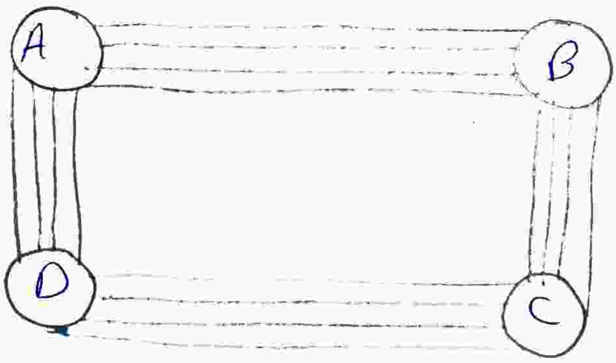
↳ 4 × 4 = 16 connection



b) suppose that all connections between A, C, what is maximum number of simultaneous connections that can be in progress?

↳ 8 ⇒ 4 for ABC & 4 ADC

c) supposte we want to make four connections between switches A, C and another four connections between B, D; can we route these calls through the four links to accomodate all eight connections?



2 ABC + 2 ADC

2 BCD + 2 BAD

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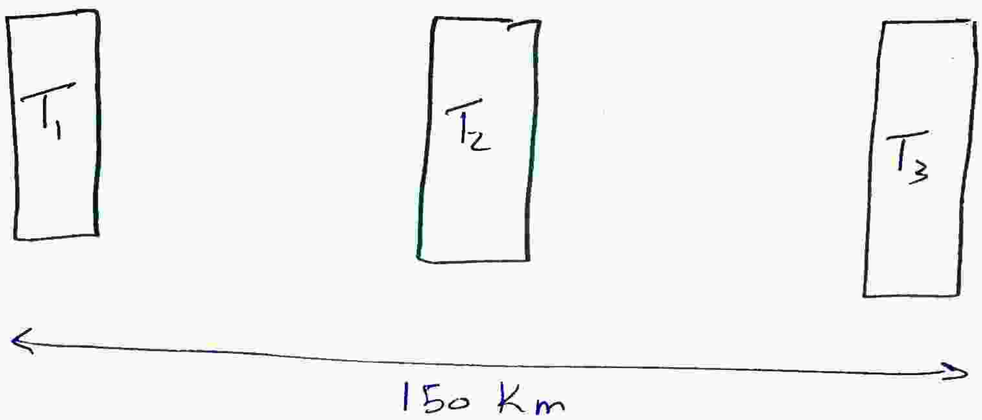
5 review the car-carvan analogy in section 1.4. Assume propagation speed of 100 km/hour.

a) suppose carvan travels 150 km, beging in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth. what is end-to-end delay?



$$d_{end\text{-}to\text{-}end} = 3\, d_{proc} + 2\, d_{prop}$$

$$= 3 * 12 * \underbrace{10}_{\text{no. of Carvans}} + 2 * \frac{75000\ m}{100\,000\ m/hr} = 96\ \text{min.}$$

b) repeat a, if no. of ~~Ca~~ Carvan Cars is 8 instead of 10.

$$d = 3 * 12 * 8 + 2 * \frac{75000\ m}{100000\ m/hr} = 94.8\ \text{min}$$

$\boxed{6}$ elementary Problem begins to explore Propagation delay and transmisson delay, two central Concepts in data networking consider 2 hosts (A, B) Connected by single link of rate R bps. suppose that A, B are separated by m meters and Propagation speed along the link is s meters/s, A is to send Packet of size L bits to Host B

a) Express Propagation delay in terms of m, s

$$d_{prop.} = \frac{m}{s}\ \text{(sec)}$$

b) express transmission time in terms of L & R.

$$d_{trans.} = \frac{L}{R} \text{ (sec)}$$

c) Ignore process and queue delay, obtain end-to-end delay

$$d_{end-to-end} = d_{trans.} + d_{prop} = \frac{m}{s} + \frac{L}{s} \text{ (Sec)}$$

d) suppose A begins to transmit packet at time ($t=0$) At time $= d_{trans}$ where is last bit of packet?

↳ last bit is put on link after finishing transmission.

e) suppose $d_{prop} > d_{trans}$ at $t = d_{trans.}$ where is 1st bit of packet?

↳ by the time trans. finishes, 1st bit still be on link towards Host B.

f) suppose $d_{prop} < d_{trans.}$ at ($t = d_{trans}$) where is 1st bit?

↳ It should reach host B before $t = d_{trans.}$

g) suppose $s = 2.5 \times 10^8$, $L = 120$ bits, $R = 56$ Kbps find distance m if $d_{trans} = d_{prop}$

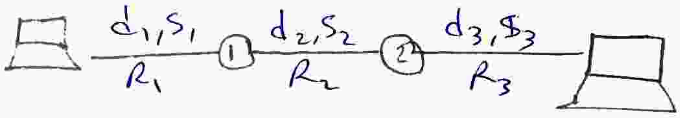
$$d_{trans.} = d_{prop}$$

$$\frac{L}{R} = \frac{m}{s} \Rightarrow m = \frac{SL}{R} = \frac{2.5 \times 10^8 \times 120}{56000}$$

$$m = 536 \text{ Km.}$$

10 Consider packet of length L which begins at end system A and travels over three links to a destination end system. three links connected by two packet switches. let d_i, S_i, R_i denote length, propagation speed and transmission rate of link i $(i=1,2,3)$ packet switch delays each packet by d_{proc}. Assuming no queuing delays, in terms of d_i, S_i, R_i what is total end-to end delay for packet?

suppose now packet is 1,500 bytes, propagation speed on all three links is 2.5×10^8 m/s, transmission rate of all 2 Mbps. $d_{proc} = 3$ msec, $L_1 = 5000$ Km, $L_2 = 4000$ Km, $L_3 = 1000$ Km what is end-to-end delay?



$$d_{end\text{-}to\text{-}end} = d_{proc_1} + d_{proc_2} + \underbrace{\frac{L}{R_1} + \frac{L}{R_2} + \frac{L}{R_3}}_{trans.} + \underbrace{\frac{d_1}{S_1} + \frac{d_2}{S_2}}_{prop}$$

with values substitute in previous ex.

$$d_{end\text{-}to\text{-}end} = 64 \text{ ms}$$

(11) in ~~t~~ above Problem assume that $R_1 = R_2 = R_3 = R$ and $d_{proc} = 0$ further suppose packet switch does not store-and-forward packets but instead immediately ~~trans~~ transmits each bit it receives before waiting for entire packet to arrive. What is $d_{end-to-end}$?

$d_{proc_1} = d_{proc_2} = 0$

immediate transmission $\Rightarrow \frac{L}{R_2} = \frac{L}{R_3} = 0$

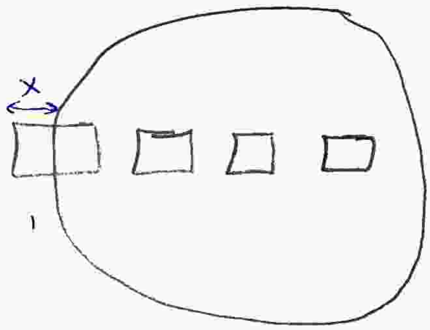
$d_{end-to-end} = \frac{d_1}{S_1} + \frac{d_2}{S_2} + \frac{L}{R}$ "1st host" $+ \frac{d_3}{S_3}$

$= \frac{5 * 10^6}{2.5 * 10^8} + \frac{4 * 10^6}{2.5 * 10^8} + \frac{10^6}{2.5 * 10^8} + \frac{1500 * 8}{2 * 10^6} = 46ms$

$\boxed{12}$ Packet switch receives packet and determines outbound ~~packet~~ link to which packet should forward. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and 4 other packets are waiting to be transmitted. Packet transmitted in order of arrival. Suppose all packets are 1500 bytes and link rate is 2 Mbps. What is queuing delay? (باقي السؤال الصفحة القادمة)

more generally, what is queuing delay when packets have length L, transmission rate R, x bits of currently being transmitted packet have been transmitted, and n packets already in queue?

$$d_{queue} = \frac{nL}{R} + \frac{L - x}{R}$$



$n = 4$, $L = 1500 * 8$ bit, $R = 2$ Mbps

$x = 750 * 8$ bit

$d = 27$ ms

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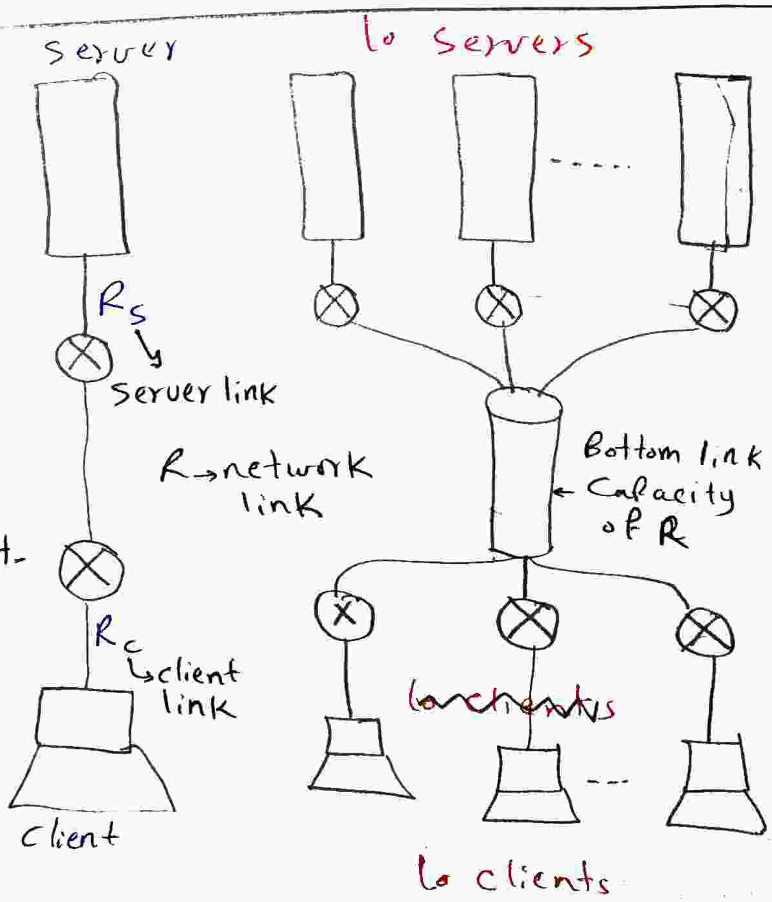
20) in this shape

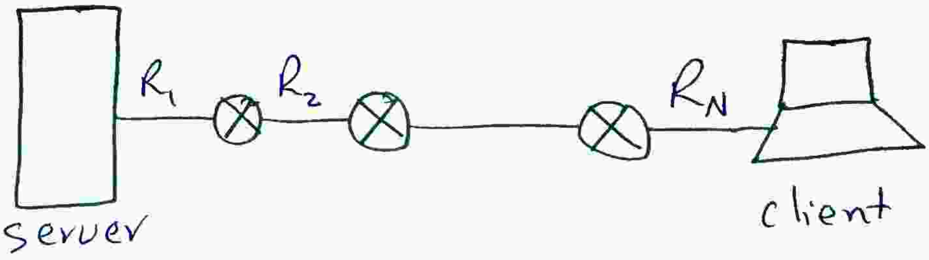
suppose we have M clients instead of 10 and all other links have abundant capacity and no traffic in network beside traffic generated by M client-server pairs. Derive general expression for throughput in terms of R_c, R_s, R, M



$$\text{Throughput} = \min\left\{R_s, R_c, \frac{R}{m}\right\}$$

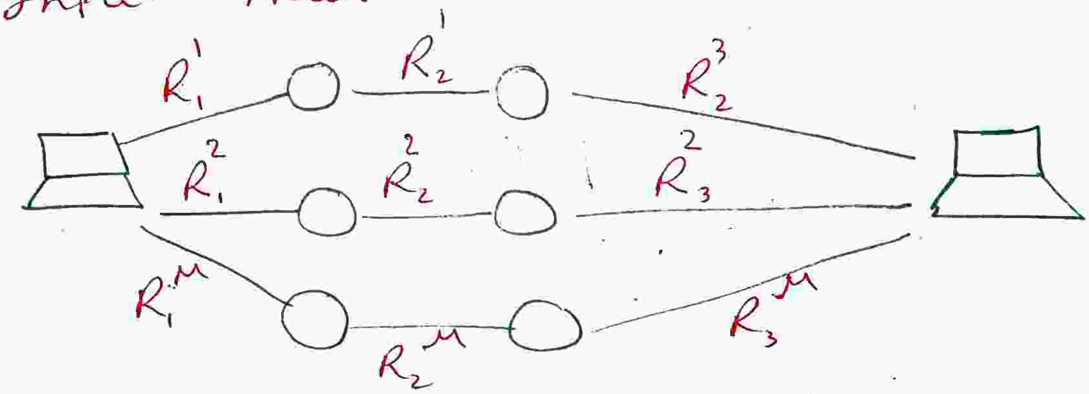
$\boxed{21}$

For ~~th~~ this Fig.



Suppose there are M paths between server, client no two paths share any link. Path K $(K=1, \dots, M)$ consists of N links with transmission rates $R_1^K, R_2^K, \dots, R_N^K$

a) if server can only use one path to send data to client, what is the Max. throughput that server can acheive?

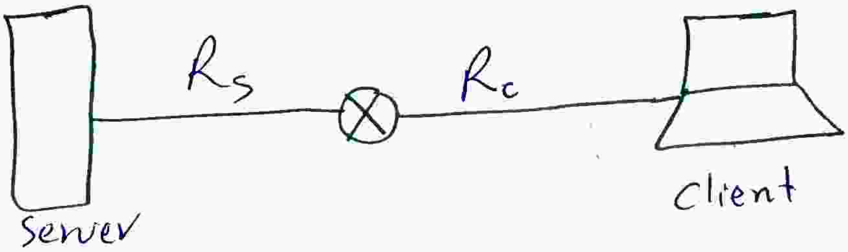


$$\text{Max throughput} = \max \left\{ \min(R_1^1, R_2^1, \dots R_N^1\}, \min(R_1^2, R_2^2, \dots R_N^2\}, \dots \min\{R_1^M, R_2^M, \dots, R_N^M\} \right\}$$

b) if server can use all M paths to send data, Derive general expression for throughput in terms of R_s, R_c, R, M

$$= \sum_{K=1}^{M} \min\{R_1^K, R_2^K, \dots R_N^K\}$$

(23)



Assume we know the bottleneck link along path from server to client is first link with rate R_s bits/sec ; suppose we send pair of packets back to back ~~form~~ from server to client, no traffic on that path. Assume each packet of size L bits, both links have same d_{prop}

a) what is the packet inter-arrival time at the destination? That is how much time elapses from when last packet arrives until last bit of second packet arrives?

↳ this is transmission delay

↳ inter-arrival time = $\frac{L}{R_s}$

b) assume 2nd link is is bottlelink ($R_c < R_s$)
is it possible that 2nd packet queues at input queue of 2nd link ? explain

↳ It is possible for 2nd packet to queue if

$$\frac{L}{R_s} + \frac{L}{R_s} + d_{prop} < \frac{L}{R_s} + \frac{L}{R_c} + d_{prop}$$

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→ Suppose queuing not to happen and server send 2nd packet T seconds after sending 1st packet How large must T be?

$$\frac{2L}{R_s} + d_{prop} + T \geqslant d_{prop} + \frac{L}{R_s} + \frac{L}{R_c}$$

$$\boxed{T \geqslant \frac{L}{R_c} - \frac{L}{R_s}}$$

(24) Suppose you would like to urgently deliver 40 terabytes data from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer. Would you prefer to transmit data via this link or instead use Fedex over-night delivery? Explain

↳ Fedex over-night delivery

for 100 Mbps link

$$\text{Transfer time} = \frac{4 * 10^{12} * 8}{100 * 10^{6}} = 3200000\,s$$

$$\simeq 37 \text{ days.}$$

↳ it will be better choice.